



US009199732B2

(12) **United States Patent**
Isaac et al.

(10) **Patent No.:** **US 9,199,732 B2**
(45) **Date of Patent:** **Dec. 1, 2015**

(54) **TILT ROTOR AIRCRAFT WITH FIXED ENGINE ARRANGEMENT**

(71) Applicant: **TEXTRON INNOVATIONS INC.**,
Providence, RI (US)

(72) Inventors: **Mark L. Isaac**, Fort Worth, TX (US);
David A. Elliott, Azle, TX (US); **Brent C. Ross**, Haslet, TX (US)

(73) Assignee: **Textron Innovations Inc.**, Providence,
RI (US)

(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/101,953**

(22) Filed: **Dec. 10, 2013**

(65) **Prior Publication Data**

US 2014/0217243 A1 Aug. 7, 2014

Related U.S. Application Data

(63) Continuation of application No. 13/357,981, filed on
Jan. 25, 2012, now Pat. No. 8,602,347.

(60) Provisional application No. 61/439,547, filed on Feb.
4, 2011.

(51) **Int. Cl.**
B64C 27/22 (2006.01)
B64C 29/00 (2006.01)
B64D 35/04 (2006.01)
B64D 35/08 (2006.01)
B64D 29/00 (2006.01)
B64D 35/00 (2006.01)

(52) **U.S. Cl.**
CPC **B64C 29/0033** (2013.01); **B64D 29/00**
(2013.01); **B64D 35/00** (2013.01); **B64D 35/04**
(2013.01); **B64D 35/08** (2013.01)

(58) **Field of Classification Search**

CPC B64C 29/02; B64C 27/28; B64C 27/10
USPC 244/56, 23 B, 17.11, 7 R, 7 A
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,974,900 A * 3/1961 Morris et al. 244/12.4
3,136,499 A * 6/1964 Kessler 244/7 C
3,284,027 A * 11/1966 Mesniere 244/12.4
3,586,262 A * 6/1971 Sherman 244/7 R

(Continued)

FOREIGN PATENT DOCUMENTS

EP 1057724 A2 12/2000
FR 2791319 A1 9/2000

OTHER PUBLICATIONS

Examination Report in related European patent application No.
12153373.1, mailed Aug. 9, 2013, 4 pages.
Extended European Search Report from related European Applica-
tion No. 12153373.1, dated Jun. 15, 2012, 8 pages.

(Continued)

Primary Examiner — Brian M O'Hara

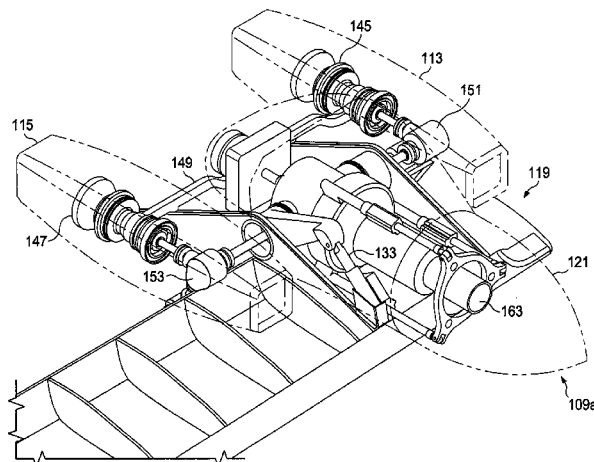
Assistant Examiner — Keith L Dixon

(74) *Attorney, Agent, or Firm* — James E. Walton

(57) **ABSTRACT**

The system of the present application includes an engine and
pylon arrangement for a tilt rotor aircraft in which the engine
is fixed in relation to a wing portion of the aircraft, while the
pylon is rotatable. The pylon supports a rotor hub having a
plurality of rotor blades. Rotation of the pylon allows the
aircraft to selectively fly in a helicopter mode and an airplane
mode, as well as any combination thereof.

20 Claims, 10 Drawing Sheets



(56)

References Cited

U.S. PATENT DOCUMENTS

3,592,412	A *	7/1971	Glatfelter	244/7 A
4,979,698	A *	12/1990	Lederman	244/7 R
5,823,470	A *	10/1998	Craig et al.	244/7 R
6,276,633	B1 *	8/2001	Balayn et al.	244/56
6,607,161	B1 *	8/2003	Krysinski et al.	244/7 A
6,659,394	B1 *	12/2003	Shenk	244/7 C
8,292,216	B1 *	10/2012	Rumberger, Jr.	244/39
8,602,347	B2 *	12/2013	Isaac et al.	244/7 A
2006/0016930	A1	1/2006	Pak	

OTHER PUBLICATIONS

Office Action dated Oct. 15, 2014 from counterpart CN App. No. 201210026136.0.

Office Action dated Jul. 9, 2014 from counterpart CA App. No. 2,766,623.

First Office Action from corresponding Chinese Application No. 201210026136.0 dated Apr. 17, 2014 issued by the Patent Office of the People's Republic of China.

Decision of Rejection dated Apr. 15, 2015 from counterpart CN App. No. 201210026136.0.

* cited by examiner

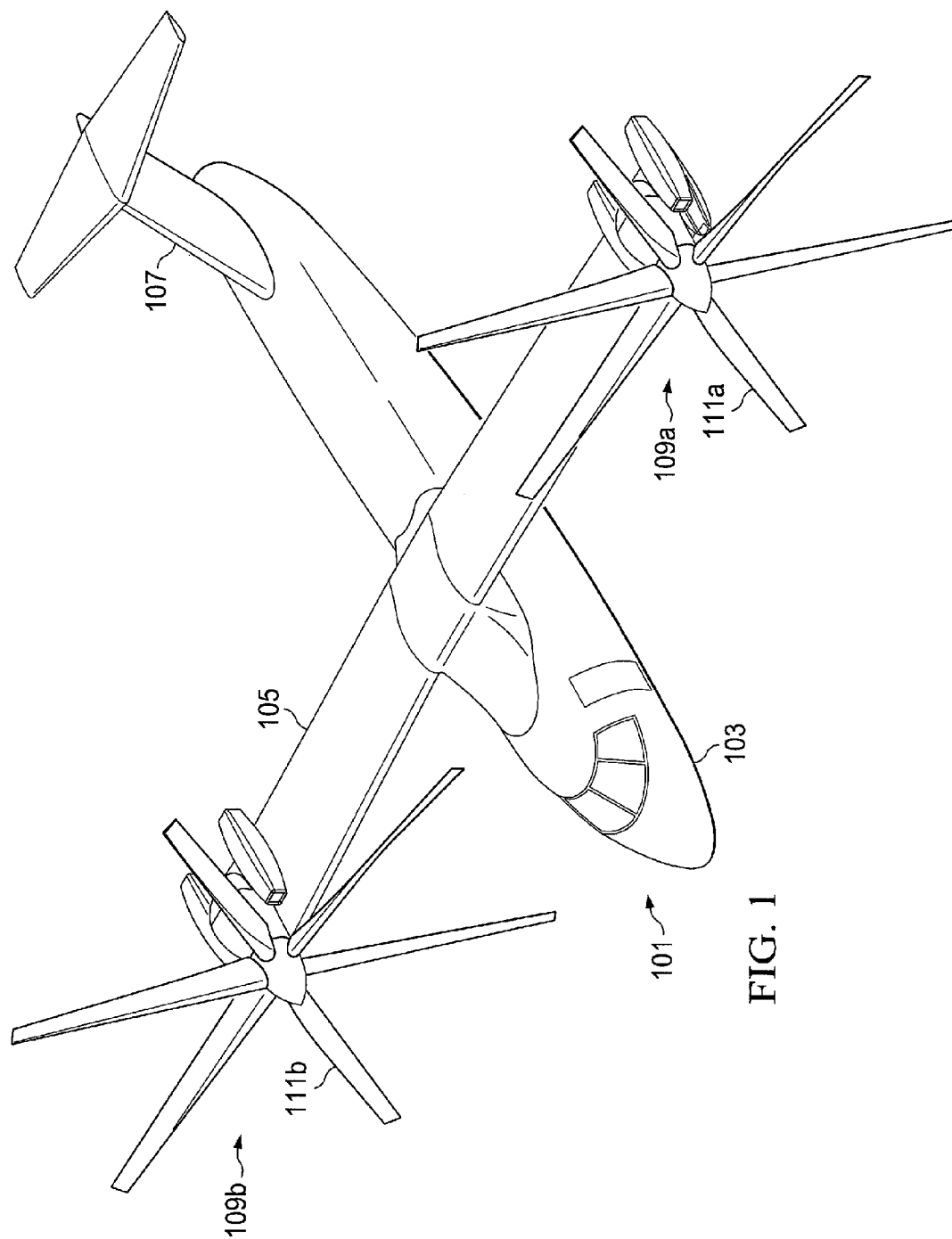
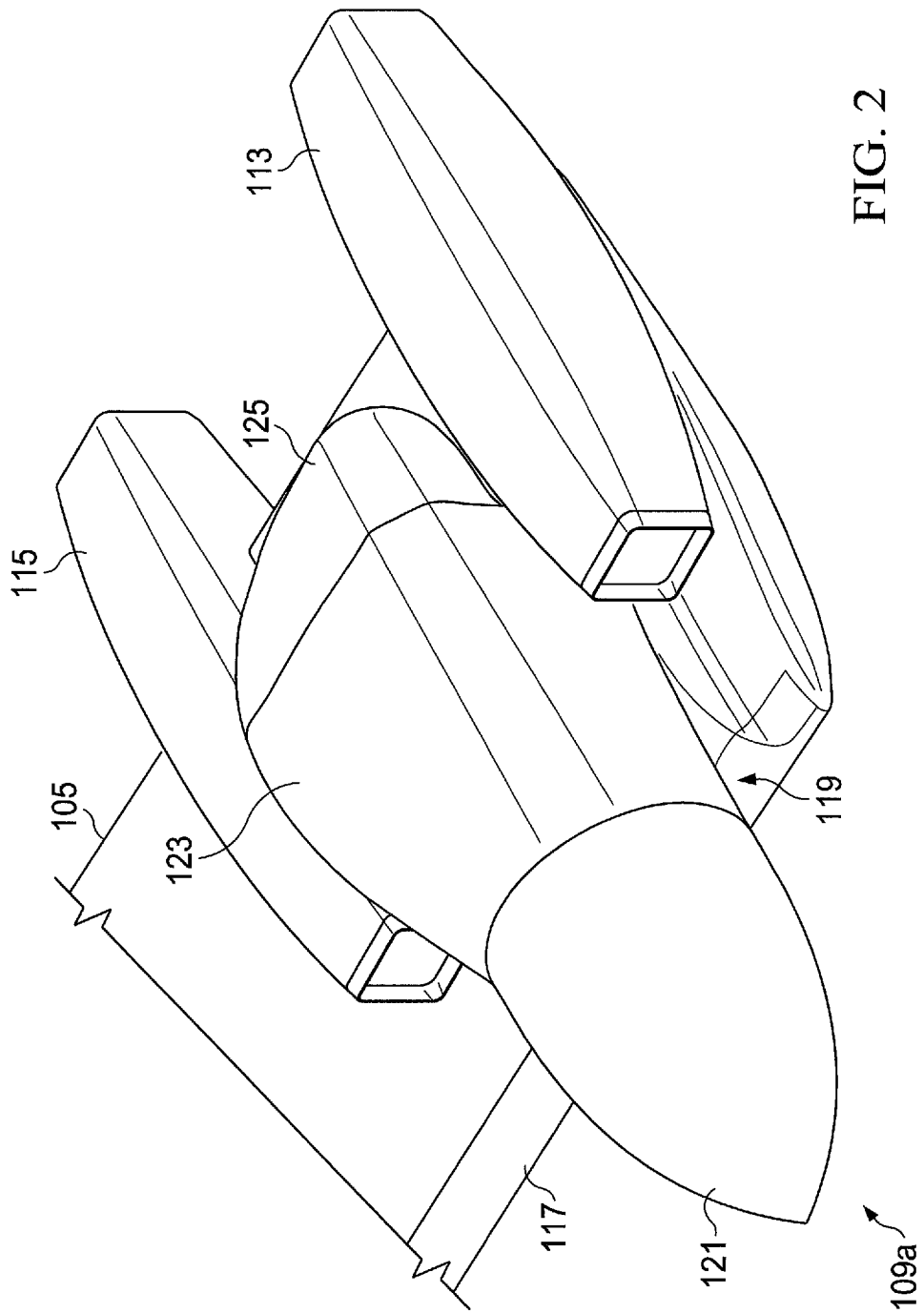


FIG. 1



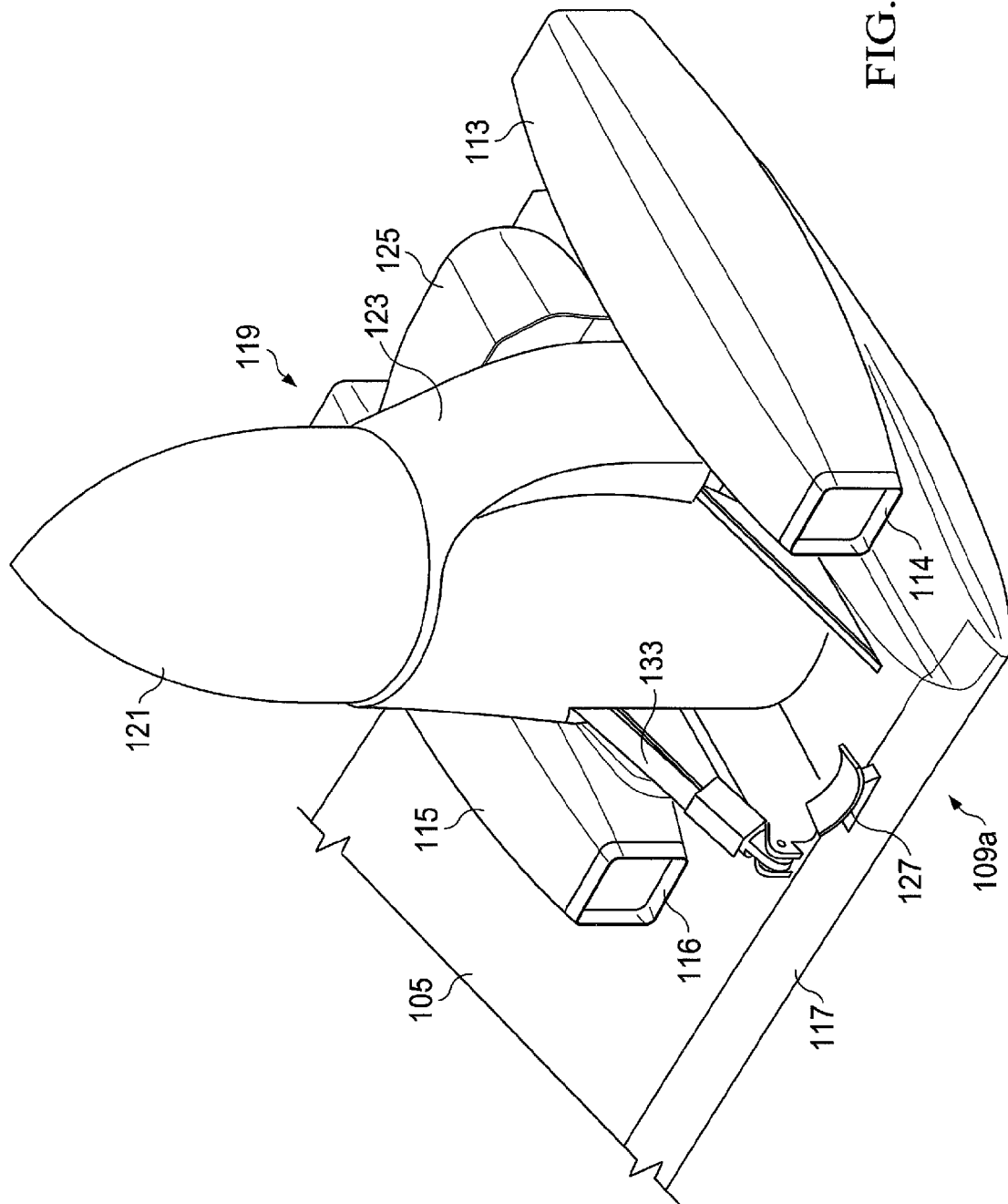
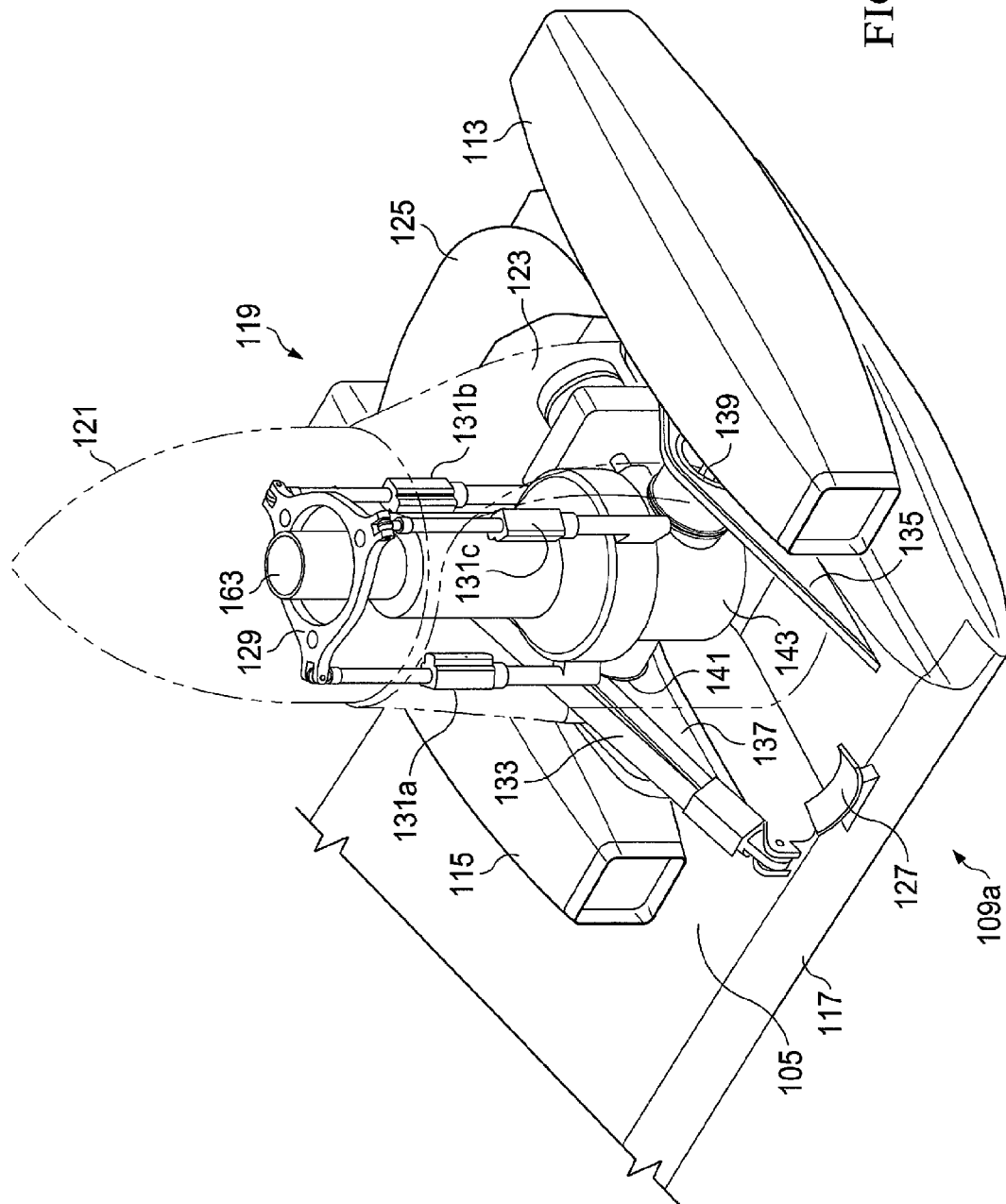
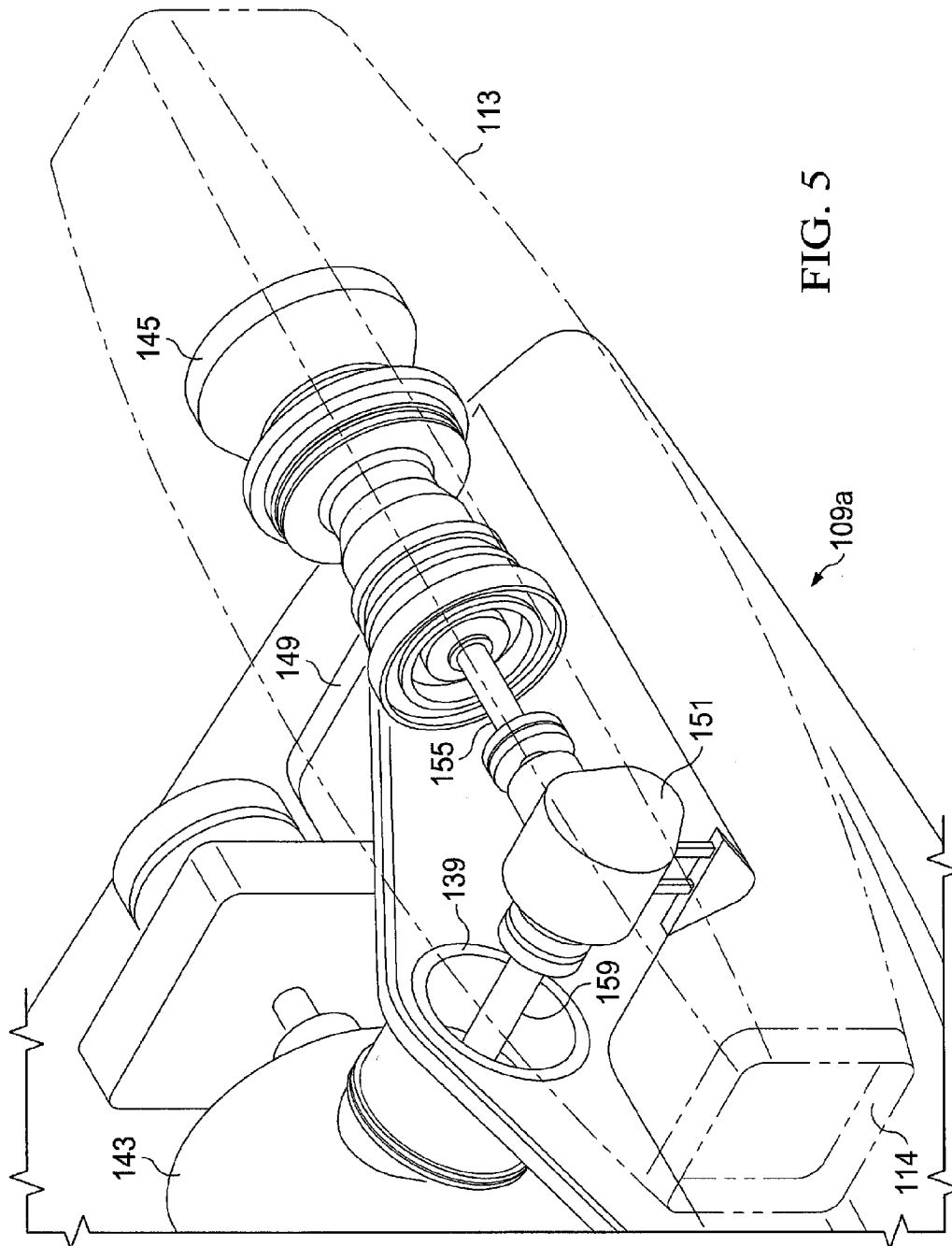


FIG. 3

FIG. 4





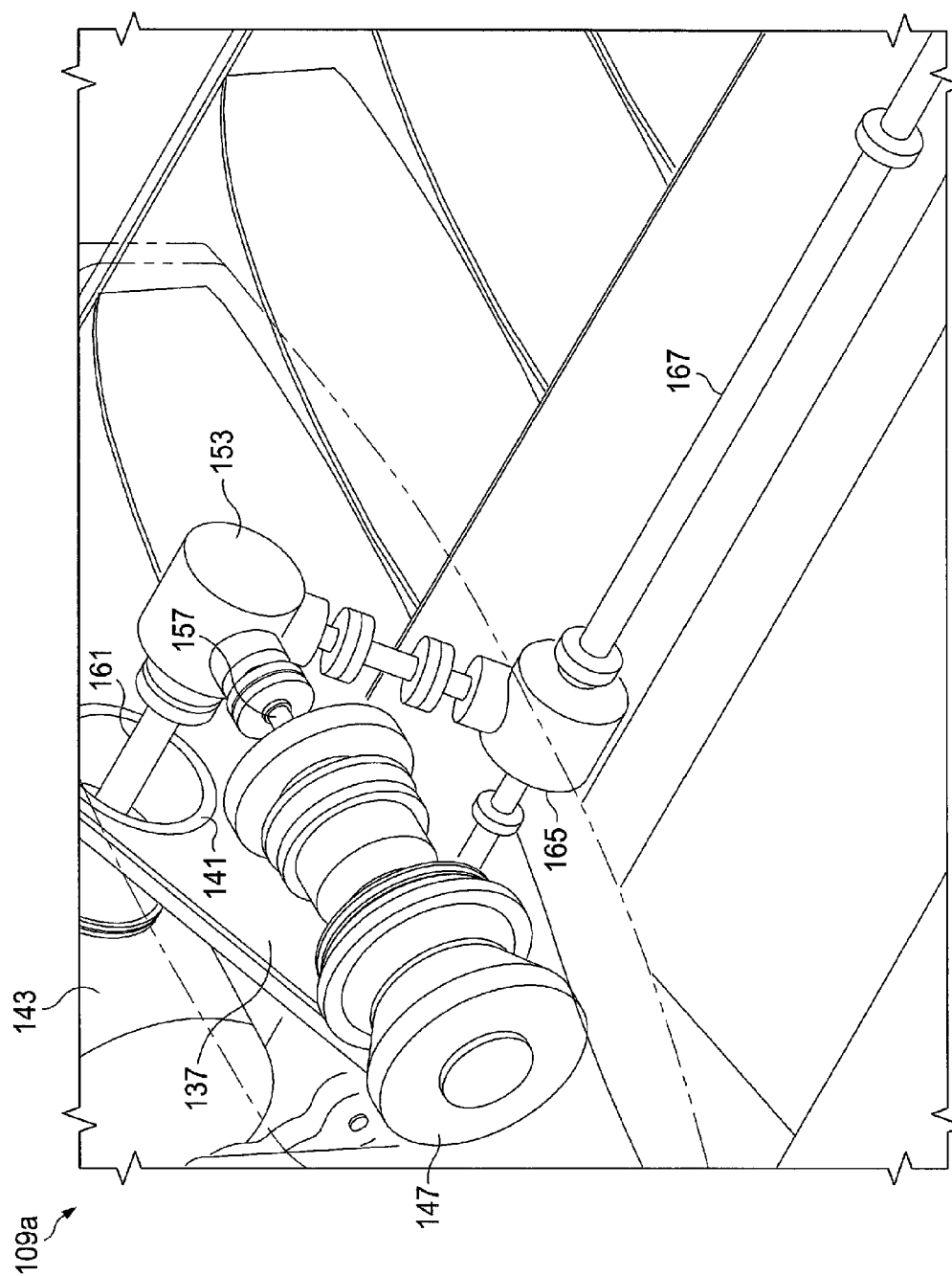


FIG. 6

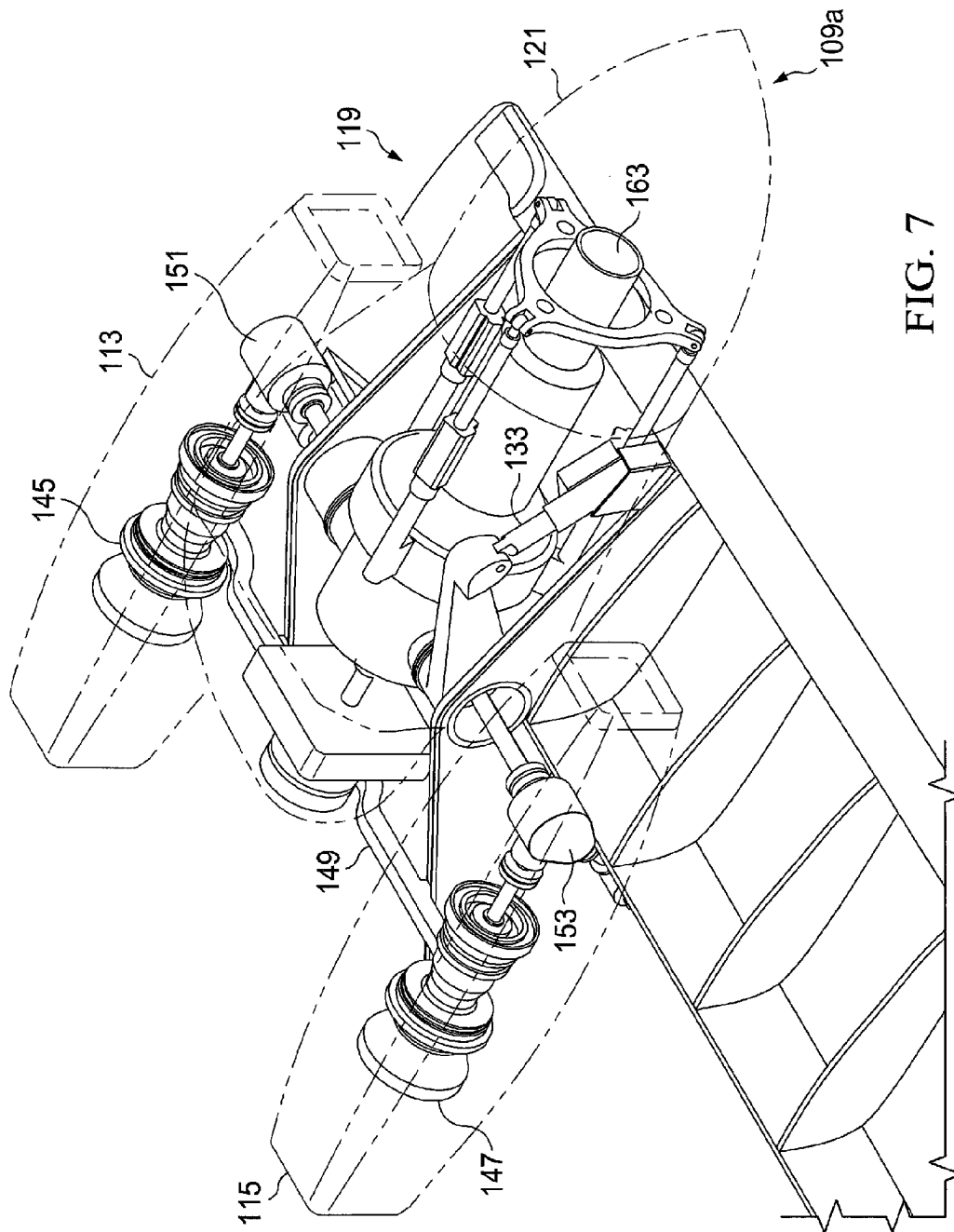


FIG. 7

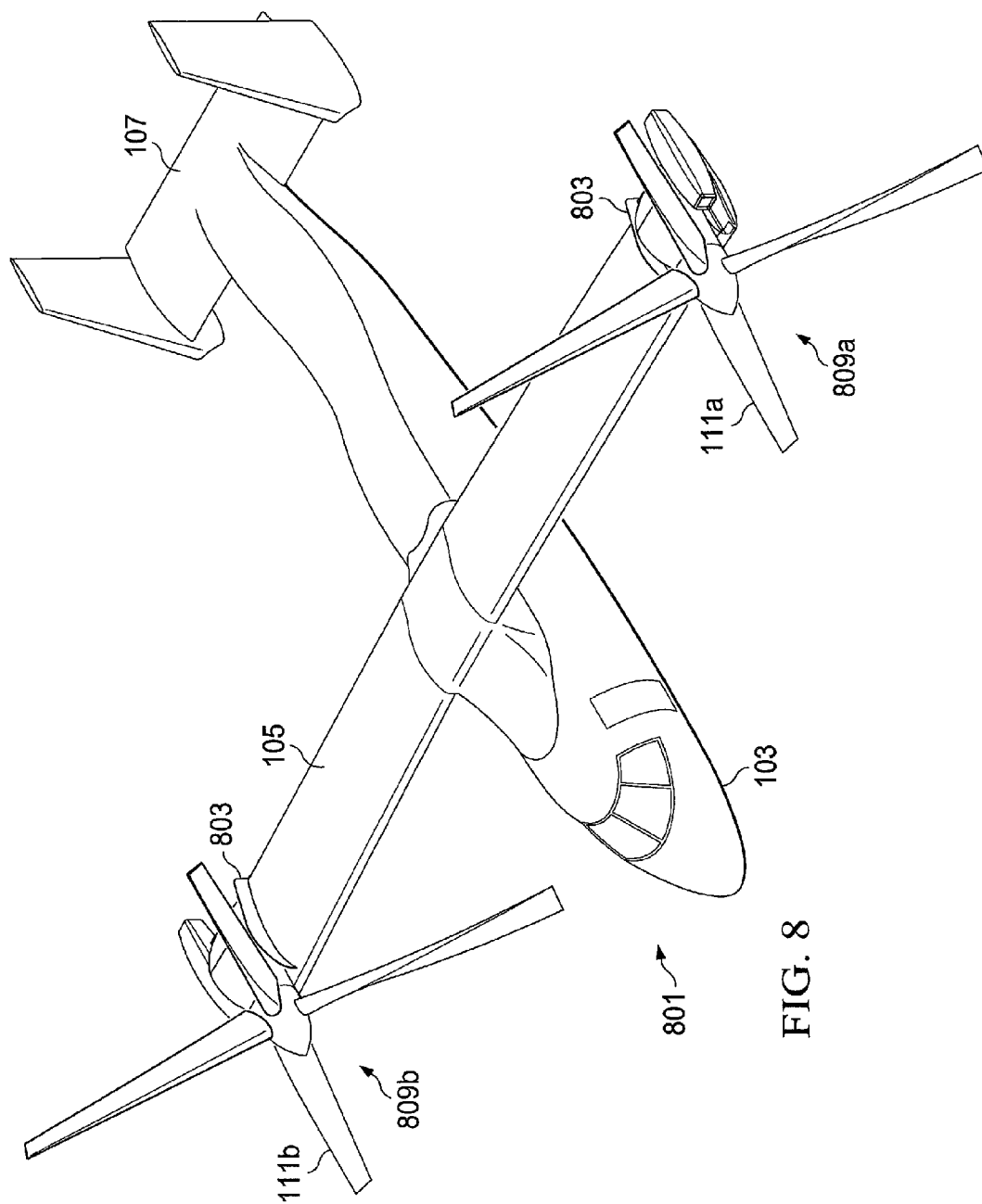
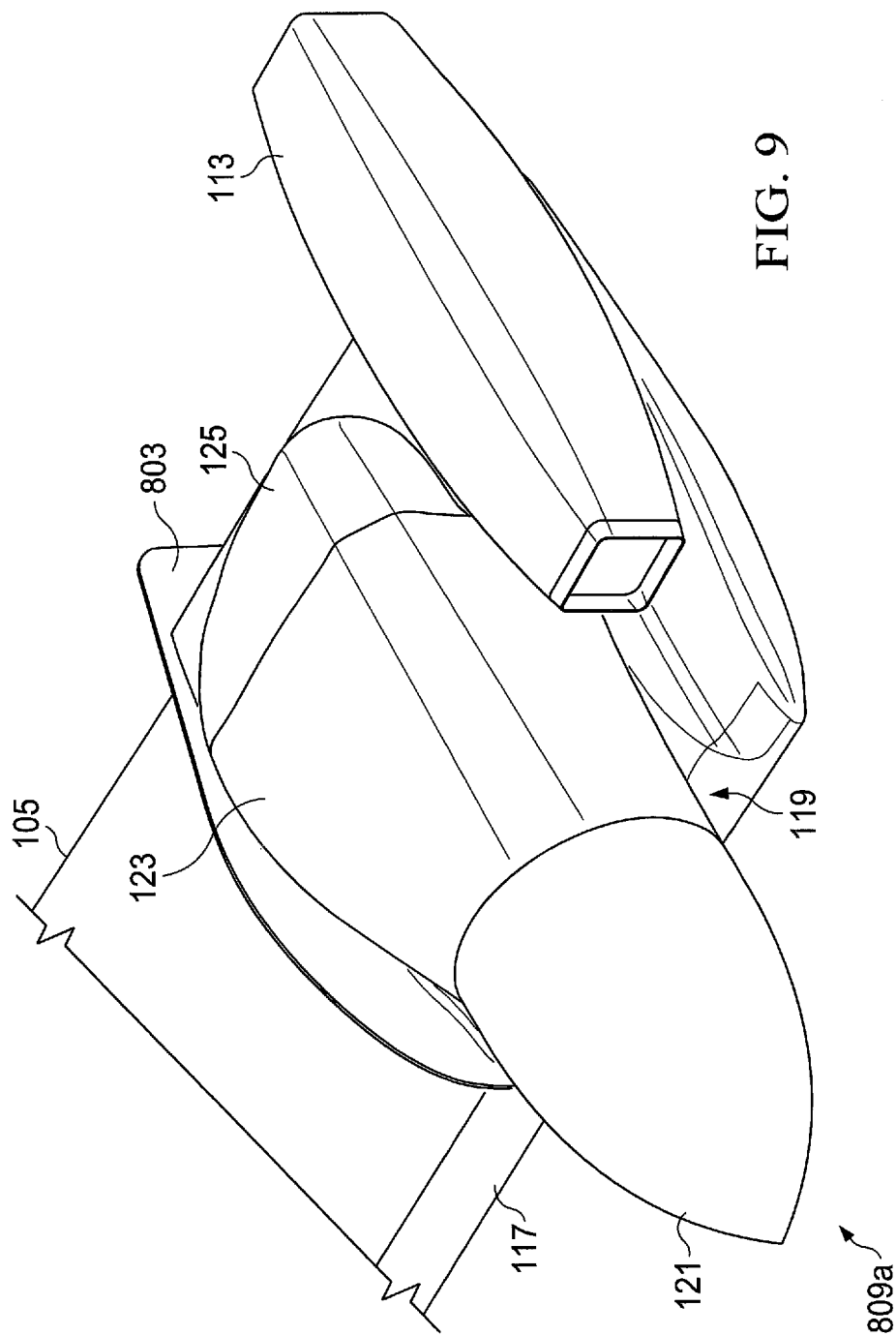


FIG. 8



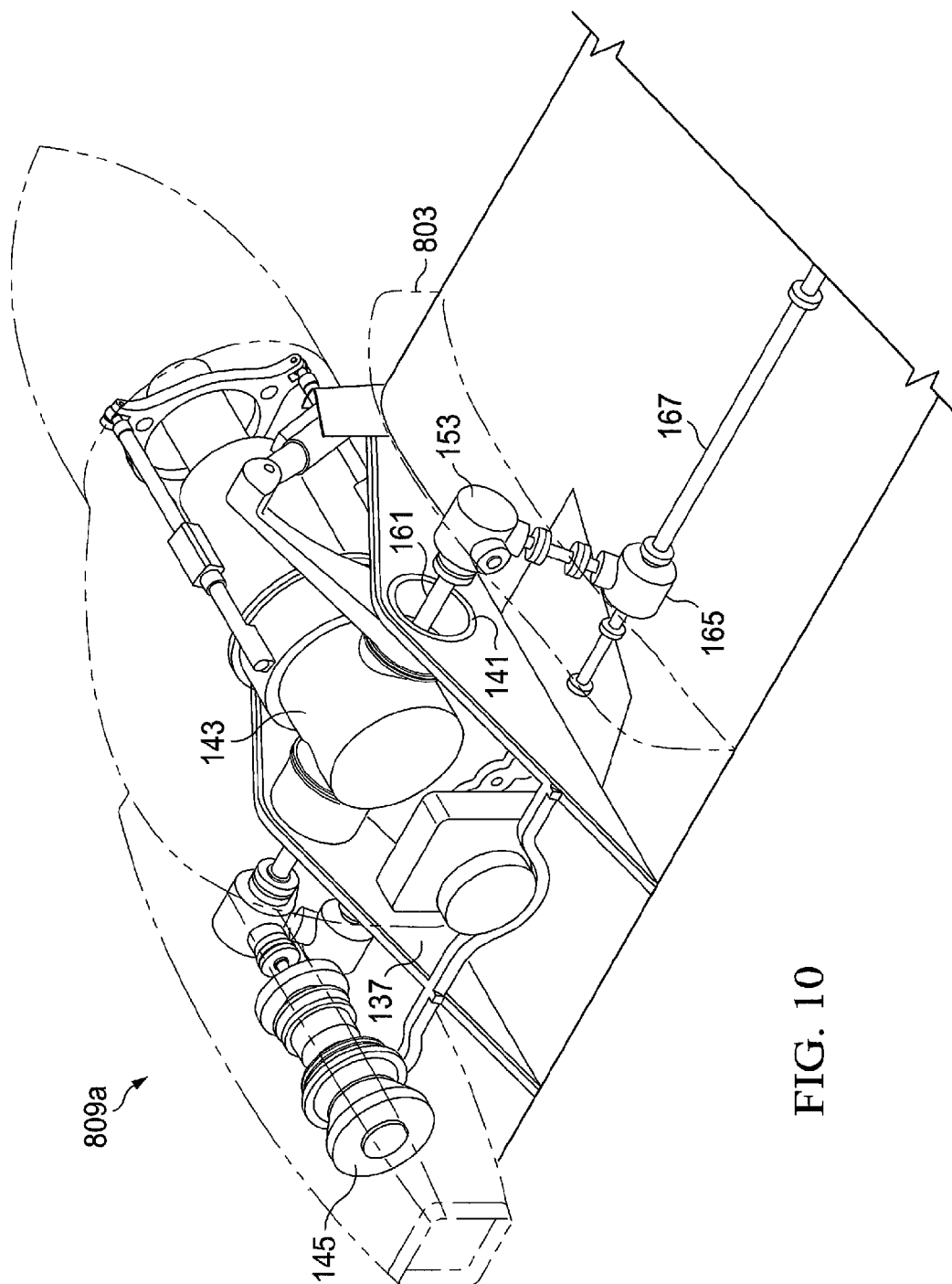


FIG. 10

1

TILT ROTOR AIRCRAFT WITH FIXED ENGINE ARRANGEMENT

This application claims the benefit of U.S. Provisional Patent Application No. 61/439,547 filed 4 Feb. 2011, titled “TILT ROTOR AIRCRAFT WITH FIXED ENGINE ARRANGEMENT;” and is a continuation of U.S. patent application Ser. No. 13/357,981 filed 25 Jan. 2012, titled “TILT ROTOR AIRCRAFT WITH FIXED ENGINE ARRANGEMENT;” all of which are hereby incorporated by reference for all purposes as if fully set forth herein.

BACKGROUND

1. Technical Field

The present application relates to an engine and pylon configuration for a tilt rotor aircraft.

2. Description of Related Art

A typical tilt rotor aircraft has wing mounted rotatable nacelles, each nacelle having an engine and rotor hub. The nacelles are selectively rotated between a helicopter mode and an airplane mode. During the helicopter mode, the nacelles are rotated to an approximate vertical position so that the tilt rotor aircraft can hover similar to a conventional helicopter. During the airplane mode, the nacelles are rotated to an approximate horizontal position so that the tilt rotor aircraft can fly similar to a fixed wing aircraft. Because the engine is located in the nacelle, the engine must be configured and certified to operate not only in a horizontal orientation, but also a vertical orientation, thus limiting engine choices. Further, a rotating engine typically requires more maintenance than a fixed engine. Even further, a rotating engine typically requires complex engine mounting structure, thus limiting maintenance/inspection access around the engine.

Hence there is a need for an improved engine and pylon configuration for a tilt rotor aircraft.

DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the system of the present application are set forth in the appended claims. However, the system itself, as well as a preferred mode of use, and further objectives and advantages thereof, will best be understood by reference to the following detailed description when read in conjunction with the accompanying drawings, wherein:

FIG. 1 is a perspective view of a tilt rotor aircraft, according to the preferred embodiment of the present application;

FIG. 2 is a perspective view of the rotor system, according to the preferred embodiment of the present application;

FIG. 3 is a perspective view of the rotor system, according to the preferred embodiment of the present application;

FIG. 4 is a perspective view of the rotor system, according to the preferred embodiment of the present application;

FIG. 5 is a partial perspective view of the rotor system, according to the preferred embodiment of the present application;

FIG. 6 is a partial perspective view of the rotor system, according to the preferred embodiment of the present application;

FIG. 7 is a partial perspective view of the rotor system, according to the preferred embodiment of the present application;

FIG. 8 is a perspective view of a tilt rotor aircraft, according to an alternative embodiment of the present application;

FIG. 9 is a perspective view of the rotor system, according to an alternative embodiment of the present application; and

2

FIG. 10 is a partial perspective view of the rotor system, according to an alternative embodiment of the present application.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Illustrative embodiments of the system of the present application are described below. In the interest of clarity, not all features of an actual implementation are described in this specification. It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developer's specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

In the specification, reference may be made to the spatial relationships between various components and to the spatial orientation of various aspects of components as the devices are depicted in the attached drawings. However, as will be recognized by those skilled in the art after a complete reading of the present application, the devices, members, apparatuses, etc. described herein may be positioned in any desired orientation. Thus, the use of terms such as “above,” “below,” “upper,” “lower,” or other like terms to describe a spatial relationship between various components or to describe the spatial orientation of aspects of such components should be understood to describe a relative relationship between the components or a spatial orientation of aspects of such components, respectively, as the device described herein may be oriented in any desired direction.

The system of the present application includes an engine and pylon arrangement for a tilt rotor aircraft in which the engine is fixed in relation to a wing portion of the aircraft, while the pylon is rotatable. The pylon supports a rotor hub having a plurality of rotor blades. Rotation of the pylon allows the aircraft to selectively fly in a helicopter mode and an airplane mode, as well as any combination thereof.

Referring to FIG. 1, a tilt rotor aircraft **101** is illustrated. In the illustrated embodiment, tilt rotor aircraft **101** includes a fuselage **103**, a wing member **105**, and a tail member **107**. Aircraft **101** further includes a first rotor system **109a** and a second rotor system **109b**. First rotor system **109a** is located on a left end portion of wing member **105**, while second rotor system **109b** is located on a right end portion of wing member **105**. First rotor system **109a** and second rotor system **109b** are substantially symmetric of each other. In the interest of clarity, only first rotor system **109a** will be discussed in detail. However, one of ordinary skill in the art will understand that the form and function of second rotor system **109b** will be fully known from the benefit of the disclosure herein related to first rotor system **109a**. Furthermore, first rotor system **109a** and second rotor system **109b** each include rotor blades **111a** and **111b**, respectively. However, in the interest of clarity, rotor blades **111a** and **111b** are omitted from some drawing views.

It should be appreciated that even though first rotor system **109a** and second rotor system **109b** are illustrated on tilt rotor aircraft **101**, first rotor system **109a** and second rotor system **109b** can be implemented on other tilt rotor aircraft. For example, an alternative embodiment can include a quad tilt rotor aircraft that has an additional wing member located aft of wing member **105**, the additional wing member can have

additional rotor systems similar to first rotor system **109a** and second rotor system **109b**. Another alternative embodiment can include an unmanned version of tilt rotor aircraft **101**. Further, first rotor system **109a** and second rotor system **109b** can be integrated into a variety of tilt rotor aircraft configurations.

Referring now to FIGS. **2** and **3**, rotor system **109a** is illustrated in an airplane mode and a helicopter mode, respectively. Rotor system **109a** includes an outboard fixed engine nacelle **113** and an inboard fixed engine nacelle **115**. A prop-rotor pylon **119** includes a plurality of rotor blades **111a** (shown in FIG. **1**) coupled to internal rotor structure located within an aerodynamic spinner fairing **121**. Prop-rotor pylon **119** includes a nacelle fairing **123** that is configured to rotate along with other rotatable pylon structure. Rotor system **109a** can include a moveable fairing panel **125** that can be actuated in the aft direction in order to provide rotational clearance for nacelle fairing **123** when prop-rotor pylon **119** is actuated into helicopter mode. Further, moveable fairing panel **125** is actuated forward when prop-rotor pylon **119** is actuated into airplane mode so as to improve aerodynamic airflow about the aft portion of prop-rotor pylon **119**. Moveable fairing panel **125** can be actuated with an independent actuator, or can be mechanically coupled to the actuator system used for actuating prop-rotor pylon **119** between airplane mode and helicopter mode.

Prop-rotor pylon **119** is rotatable between the airplane mode, in which prop-rotor pylon **119** is positioned approximately horizontal (as shown in FIG. **2**), and a helicopter mode (as shown in FIG. **3**), in which prop-rotor pylon **119** is positioned approximately vertical. During the airplane mode, vertical lift is primarily supplied by the airfoil profile of wing member **105**, while rotor blades **111a** and **111b** in each prop-rotor pylon **119** provide forward thrust. During the helicopter mode, vertical lift is primarily supplied by the thrust of rotor blades **111a** and **111b** in each prop-rotor pylon **119**. It should be appreciated that tilt rotor aircraft **101** may be operated such that prop-rotor pylons **119** are selectively positioned between airplane mode and helicopter mode, which can be referred to as a conversion mode.

Rotor system **109a** can include a pylon downstop **127** for securing prop-rotor pylon **119** when prop-rotor pylon **119** is positioned in the airplane mode. Further, pylon downstop **127** can be beneficial for relieving stresses on the actuator(s), such as a conversion actuator **133**, used for selectively rotating prop-rotor pylon **119** between airplane mode position and helicopter mode position.

Outboard fixed engine nacelle **113** includes an outboard engine air inlet **114**. Similarly, inboard fixed engine nacelle **115** includes an inboard engine air inlet **116**. Air inlets **114** and **116** can be positioned aft of a leading edge portion **117** of wing member **105**; however, an alternative embodiment can include the positioning of air inlets **114** and **116** forward of leading edge portion **117** of wing member **105**. The exact position of air inlets **114** and **116** is implementation specific and dependent in part upon the aerodynamic ram air effects that can be achieved through selective placement.

It should be appreciated that the wing tip portion of wing member **105** can be lengthened to customize an aspect ratio of wing member **105** in accordance with implementation specific aerodynamic lift requirements. As such, it should be understood that even though outboard fixed engine nacelle **113** is illustrated approximately abutting the wing tip portion of wing member **105**, an alternative embodiment may include the wing tip portion extending well beyond outboard fixed engine nacelle **113**.

When rotor system **109a** is in helicopter mode, airflow downwash from rotor blades **111a** and **111b** can flow, when uninhibited, along the upper surface of wing member **105**, thereby negatively affecting vertical lift performance. Inboard fixed engine nacelle **115** is located in part to act as an air dam to thwart downwash airflow along the upper surface of wing member **105**, the downwash airflow being in the direction from the root end to the tip end of wing member **105**.

Referring now also to FIGS. **4-7**, rotor system **109a** is illustrated in further detail. A swashplate **129** is coupled rotor blades **111a** via a plurality of pitch links (not shown). Swashplate actuators **131a-131c** are configured to selectively actuate swashplate **129**, thereby selectively changing the pitch of rotor blades **111a** so as to affect thrust, lift, and direction of aircraft **101** during operation. For example, swashplate **129** can be selectively tilted to effect cyclic pitch change of rotor blades **111a**. Further, swashplate **129** can be actuated to effect collective pitch change of rotor blades **111a**. A conversion actuator **133** is configured to selectively actuate prop-rotor pylon **119** between a helicopter mode position and an airplane mode position, while the engines **145** and **147** remain fixed on wing member **105**. It should be appreciated that conversion actuator **133** may be of a variety of configurations. For example, conversion actuator **133** may be a linear actuator or a rotary actuator, the exact actuator type being implementation specific. A prop-rotor gearbox housing **143** of prop-rotor pylon **119** is pivotally mounted on an outboard rib bearing **139** within an outboard rib **135**, and an inboard rib bearing **141** within an inboard rib **137**.

An outboard engine **145** and an inboard engine **147** can be structurally mounted on an engine support beam **149** near a trailing edge portion of wing member **105**. Outboard engine **145** is mechanically coupled to an outboard input gearbox **151**, via an outboard input driveshaft **155**, such that torque is transferred to outboard input gearbox **151** from outboard engine **145**. Similarly, inboard engine **147** is mechanically coupled to an inboard input gearbox **153**, via an inboard input driveshaft **157**, such that torque is transferred to inboard input gearbox **153** from inboard engine **147**. Torque is transferred to a main rotor mast **163** from outboard input gearbox **155** and inboard input gearbox via an outboard gearbox driveshaft **159** and an inboard gearbox driveshaft, respectively.

Inboard input gearbox **153** can optionally be coupled to an accessory input gearbox **165** and further an interconnect drive shaft **167**. Interconnect drive shaft **167** can be used to drive an auxiliary gearbox located within fuselage **103**. In an alternative embodiment, interconnect drive shaft **167** can be sized to carry torque sufficient to drive rotor blades **111b** on rotor system **109b**, which can provide an additional safety factor in an engine failure situation.

The configuration of rotor system **109a** allows engines **145** and **147** to remain fixed on wing member **105**, while only prop-rotor pylon **119** rotates to allow aircraft **101** to fly both in a helicopter mode, an airplane mode, and conversion mode. Attempts have been made in prior tilt rotor aircraft configurations to locate fixed engines within a fuselage of the aircraft; however, such a configuration requires an interconnect drive system to carry full engine power out to the wing tip mounted rotor and prop-rotor drive gearboxes, which can degrade safety and reliability of the drive system. In contrast, rotor system **109a** is configured such that the engines **145** and **147** are located directed adjacent to prop-rotor pylon **119**, so that only a short input shaft system is required to carry full engine power. As such, the short input drive shaft system from each engine to the prop-rotor pylon provides increased safety, reliability, and efficiency. In the illustrated embodiment, full engine power is carried in input driveshafts **155** and **157**, as

5

well as gearbox drive shafts **159** and **161**. Further, by having two engines **145** and **147**, a factor of safety is realized, thus an interconnect drive shaft configured to carry engine power between rotor systems **109a** and **109b** is not required. However, having an interconnect drive shaft configured to carry engine power between rotor systems **109a** and **109b** is an alternative configuration that may be desirable when a significant hedge against multiple engine failure is desired. Furthermore, configuring rotor system **109a** with fixed engines, instead of engines that rotate, results in a significant reduction in engine certification costs, complexity, and expense. Furthermore, a rotor system **109a** with fixed engines, instead of engines that rotate, can provide a substantial increase in engine options and availabilities, thus contributing to aircraft cost reduction.

Referring now to FIGS. **8-10**, a tilt rotor aircraft **801** is illustrated as an alternative embodiment of tilt rotor aircraft **101**. Tilt rotor aircraft **801** is substantially similar in form and function to tilt rotor aircraft **801**, except as noted herein. For example, tilt rotor aircraft **801** is different from tilt rotor aircraft **101** in that inboard fixed engine nacelle **115** is omitted in rotor systems **809a** and **809b**. As such, tilt rotor aircraft **801** has only a single fixed engine in each rotor system **809a** and **809b**. Further, an optional wing fence **803** can be utilized to act as an air dam to thwart downwash airflow along the upper surface of wing member **105**, the downwash airflow being in the direction from the root end to the tip end of wing member **105**. While tilt rotor aircraft **801** has only a single engine **145** for powering prop-rotor pylon **119**, it can be especially desirable for interconnect drive shaft **167** to be sized to carry torque sufficient to drive rotor blades **111 b** on rotor system **809b**, which can provide an additional safety factor in an engine failure situation. In the illustrated embodiment, inboard input gearbox **153** mechanically transmits power from outboard engine **145** to accessory input gearbox **165** and further to interconnect drive shaft **167**. It should be understood that the exact configuration of the drive shafts and gearboxes is implementation specific.

It is apparent that a rotor system with significant advantages has been described and illustrated. The tilt rotor fixed engine system provides for a horizontal, permanent engine mounting which reduces certification costs, increases available engine choices, and reduces maintenance costs and scheduled maintenance times. The proximity of the fixed engines to the rotating pylon also increases safety with regard to drive shaft failures, bearing lives, and coupling needs. Although the system of the present application is shown in a limited number of forms, it is not limited to just these forms, but is amenable to various changes and modifications without departing from the spirit thereof.

The invention claimed is:

1. A rotor system for a tilt rotor aircraft, the rotor system comprising:
 - an outboard engine in a first fixed location on a wing member of the tilt rotor aircraft;
 - a prop-rotor pylon in power communication with the outboard engine, the prop-rotor pylon being configured to selectively rotate between a vertical position and a horizontal position, the prop-rotor pylon comprising a plurality of rotor blades;
 - an outboard input drive shaft coupled between the outboard engine and an outboard input gearbox; and
 - an outboard gearbox drive shaft being perpendicular to the outboard input drive shaft and coupled to the outboard input drive shaft;

6

wherein the prop-rotor pylon selectively rotates about the outboard gearbox drive shaft when orienting between the vertical position and the horizontal position; and wherein the prop-rotor pylon rotates relative to the wing member.

2. The rotor system according to claim 1, wherein the outboard engine is located outboard of the prop-rotor pylon.

3. The rotor system according to claim 1, the prop-rotor pylon further comprising:

- a swashplate;
- a gearbox; and
- a nacelle fairing configured as an aerodynamic housing for the swashplate and the gearbox.

4. The rotor system according to claim 1, wherein the outboard gearbox drive shaft traverses through an interior of an outboard rib bearing, the outboard rib bearing providing rotational support for the prop-rotor pylon against a fixed outboard rib member.

5. The rotor system according to claim 1, the prop-rotor pylon further comprising:

- a nacelle fairing configured as an aerodynamic housing for internal components located therein;
- a fairing panel located aft of the nacelle fairing, the fairing panel being moveable between a closed position and an open position, the closed position providing aerodynamic efficiency when the prop-rotor pylon is the horizontal position, the open position providing clearance for the prop-rotor pylon to rotate into the vertical position.

6. The rotor system according to claim 1, further comprising:

- an inboard engine in a second fixed location on the wing member of the tilt rotor aircraft.

7. The rotor system according to claim 6, further comprising:

- an inboard input drive shaft coupled between the inboard engine and an inboard input gearbox; and
- an inboard gearbox drive shaft coupled between the inboard input gearbox and a gearbox located in the prop-rotor pylon.

8. The rotor system according to claim 7, further comprising:

- an accessory drive shaft coupled between the inboard input gearbox and an accessory input gearbox;
- an interconnect drive shaft coupled to the accessory input gearbox.

9. The rotor system according to claim 8, wherein the interconnect drive shaft is coupled to an accessory gearbox located in a fuselage portion of the aircraft.

10. The rotor system according to claim 8, wherein the interconnect drive shaft is coupled to a gearbox configured for driving a second prop-rotor pylon located on an opposite portion of the wing member.

11. A tilt rotor aircraft comprising:

- a fuselage;
 - a wing member;
 - an outboard engine in a first fixed location on the wing member of the tilt rotor aircraft;
 - an inboard engine in a second fixed location on the wing member of the tilt rotor aircraft; and
 - a prop-rotor pylon powered by the outboard engine and the inboard engine, the prop-rotor pylon being configured to selectively rotate between a vertical position and a horizontal position, the prop-rotor pylon comprising a plurality of rotor blades;
- wherein the outboard engine is located outboard of the prop-rotor pylon;

7

wherein the inboard engine is located inboard of the prop-rotor pylon; and
wherein the prop-rotor pylon rotates relative to the wing member.

12. The tilt rotor aircraft according to claim **11**, wherein the outboard engine and the prop-rotor pylon being located on an outboard portion of the wing member, the outboard portion being a selected distance from the fuselage.

13. The tilt rotor aircraft according to claim **11**, the prop-rotor pylon further comprising:

a swashplate;
a gearbox; and
a nacelle fairing configured as an aerodynamic housing for the swashplate and the gearbox.

14. The tilt rotor aircraft according to claim **11**, further comprising:

an outboard input drive shaft coupled between the outboard engine and an outboard input gearbox; and
an outboard gearbox drive shaft coupled between the outboard input gearbox and a gearbox located in the prop-rotor pylon.

15. The tilt rotor aircraft according to claim **14**, wherein the outboard gearbox drive shaft traverses through an interior of an outboard rib bearing, the outboard rib bearing providing rotational support for the prop-rotor pylon against a fixed outboard rib member.

16. The tilt rotor aircraft according to claim **11**, the prop-rotor pylon further comprising:

8

a nacelle fairing configured as an aerodynamic housing for internal components located therein;

a fairing panel located aft of the nacelle fairing, the fairing panel being moveable between a closed position and an open position, the closed position providing aerodynamic efficiency when the prop-rotor pylon is the horizontal position, the open position providing clearance for the prop-rotor pylon to rotate into the vertical position.

17. The tilt rotor aircraft according to claim **11**, wherein the prop-rotor pylon is located between the outboard engine and the inboard engine.

18. The tilt rotor aircraft according to claim **11**, further comprising:

an inboard input drive shaft coupled between the inboard engine and an inboard input gearbox; and
an inboard gearbox drive shaft coupled between the inboard input gearbox and a gearbox located in the prop-rotor pylon.

19. The tilt rotor aircraft according to claim **11**, further comprising:

a conversion actuator configured to selectively rotate the prop-rotor pylon.

20. The tilt rotor aircraft according to claim **11**, wherein the outboard engine and the inboard engine are directly adjacent the prop-rotor pylon.

* * * * *